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TEC & SCOTEC
GUIDANCE FOR STUDENTS

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TECHNICIAN EDUCATION COUNCIL

Certificate Programme in Telecommunications

Sets of model questions and answers for Technician Education Council (TEC) units are given below. The questions illustrate the types of questions that students may encounter, and are useful as practice material for the skills learned during the course.

Where additional text is given for educational purposes, it is shown within square brackets to distinguish it from information expected of students under examination conditions. Representative time limits are shown for each question, and care has been taken to give model answers that reflect these limits.

We would like to emphasise that the questions are not representative of questions set by any particular college.

TEC: RADIO II

TEC unit number U81/754. Students are advised to read the notes above

Q1 With reference to long-distance high-frequency radio transmission, explain, in terms of frequency and mode of propagation, the difference between ground waves and sky waves. *(15 min)*

A1 The essential difference between a ground wave and a sky wave is that the former is a surface wave, whereas a sky wave depends on the reflecting properties of the ionosphere to reflect the signal around the Earth.

A ground wave must be launched as a vertically-polarised wave. Some of the energy transmitted penetrates the Earth's surface and, thus, the attenuation of the signal depends on the conductivity of the Earth and the surface roughness, so that propagation is more effective at low frequencies and over the sea. Because the transmission is a surface wave, it tends to follow the curvature of the Earth, the limit of transmission being determined by the quality of the surface medium and the frequency of operation. Once communication has been established by the use of ground waves, a permanent link is obtained which is not subject to fluctuation.

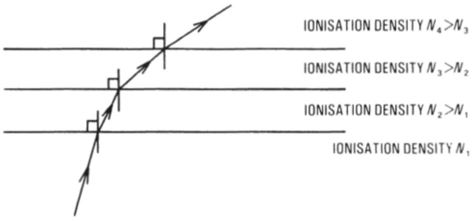
When a wave is launched from an aerial, it is possible for both sky waves and ground waves to be generated. At low frequencies, ground waves are predominant, since the majority of the energy is converted into a surface wave. At high frequencies, ground waves are greatly attenuated, but it is possible to transmit signals at an angle above the horizontal and obtain reflection from the ionosphere, thus permitting reception to be obtained at distances considerably beyond the horizon.

The ionosphere consists of layers of ionised gases at heights of 48–400 km above the Earth's surface. These layers cause the incident radio waves to change direction by a process of refraction. If the density of the layers is sufficient, the direction of the waves can be changed so that they return to Earth and, thus, the ionised layers act like a mirror, reflecting the incident waves back to Earth some distance beyond the horizon. The f_1 layer, at 145–241 km, and the f_2 layer, at 322 km above the Earth, have most effect on high-frequency radio propagation. Signals may also reach a receiver after travelling by a series of multiple reflections between the ionosphere and the Earth.

The disadvantage of sky-wave communication between 2 points is that the transmission path is not very stable. The amount of refraction depends on the ionisation at any one time and, since this is caused by ultra-violet radiation from the sun, it varies with the time of day and the degree of sunspot activity.

Q2 Explain the terms
(a) refraction, and
(b) maximum usable frequency.
(15 min)

A2 (*a*) When a radio wave enters an ionised region of gas from a non-ionised region, or from an ionised region of lesser density, it experiences an increase in phase velocity. As a result, a radio wave passing into the ionosphere, at some angle to the vertical, bends further away from the vertical as it moves into a region of higher ionisation. If the rate of change of ionisation with height is sufficient, the wave is refracted back towards the Earth.


IONISATION DENSITY $N_4 > N_3$
IONISATION DENSITY $N_3 > N_2$
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IONISATION DENSITY N_1

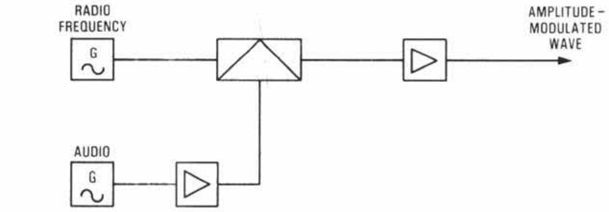
The sketch illustrates how a radio wave, incident on successively more-densely ionised layers of the ionosphere, is refracted.

(*b*) The maximum usable frequency (MUF) is the highest frequency at which communication may be established over a given path between 2 fixed points. If a frequency greater than the MUF is transmitted, refraction in the ionosphere is reduced, and the consequent skip distance is increased, thereby placing the receiver in the dead zone. The MUF depends on the time of day and the season, since these affect the state of the ionosphere.

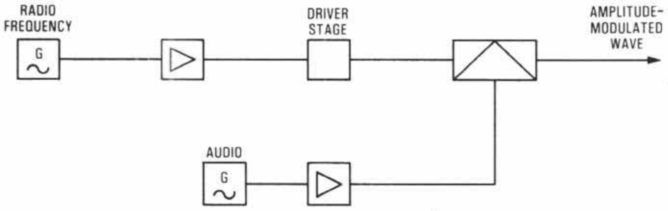
Q3 Define low-level and high-level amplitude modulation. (*15 min*)

A3 Basically an amplitude-modulated signal is a mixture of 2 waves: the carrier wave and the audio-frequency wave, which is sometimes known as the *intelligence*. The carrier wave is derived from a highly-stable oscillator; for example, a crystal-controlled oscillator. This carrier wave is amplified and frequency multiplied by several stages of radio-frequency amplifiers and frequency multipliers, respectively, until a suitable output level and frequency are achieved.

At some stage in the transmitter, the audio frequency is injected to amplitude modulate the carrier. Modulation can take place either at an early stage of the carrier wave processing, when the carrier is at a low level (see sketch (*a*)) (in which case it is the amplitude-modulated wave which is amplified) or it can be injected at the final amplification stage when the carrier has reached its final power level (see sketch (*b*)). These 2 methods are classified as low-level and high-level modulation respectively.



(*a*)



(*b*)

Q4 Explain the need for frequency stability in radio transmission and how it can be achieved practically. (*10 min*)

A4 Because frequencies used for radio transmission have been allocated by international agreement, the frequency of a radio transmitter must adhere to the designated frequency. If the frequency of the transmitter were to drift in either direction from the designed frequency, then this could cause considerable interference with adjacent channels. In modes of transmission where the suppressed-carrier must be re-inserted at the receiver at the correct frequency it is vitally important that the transmitter carrier frequency is stable.

The transmitted carrier frequency must originate from a stable oscillator; that is, it must be able to produce a constant frequency at all times. One method of achieving this is to use an oscillator the frequency of which is controlled by a piezo-electric crystal.

It is common practice to use frequency multipliers to achieve the desired frequency from a low-frequency crystal-controlled oscillator.

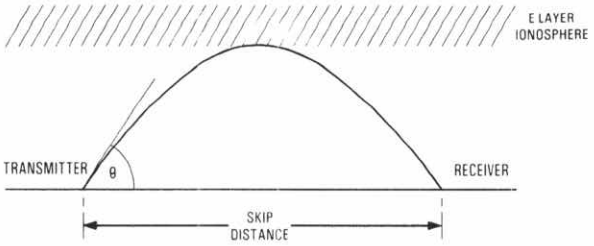
Typically, a stability of ±1 part in 10^6 is required for a transmitter.

Q5 Explain any 3 of the following terms with sketches where appropriate
- (*a*) *skip distance*,
- (*b*) *beamwidth*,
- (*c*) *radiation pattern, and*
- (*d*) *fading*

(*20 min*)

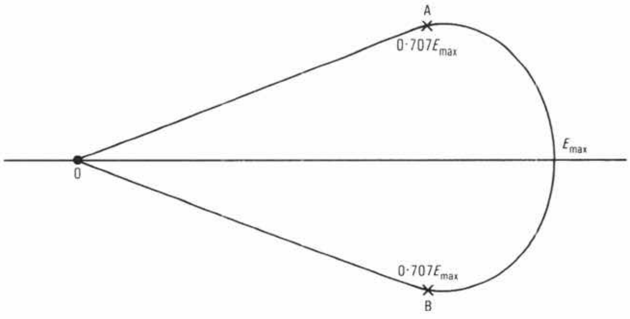
A5 Any 3 of the following.

(*a*) Skip distance is the minimum distance at which radio waves of a given frequency can be received from a given transmitter. This applies to a given direction of transmission at a given angle of incidence, θ, to the earth's surface. This is shown in sketch (*a*).



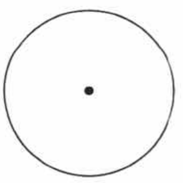
(*a*)

(*b*) Beamwidth is a measure of the directivity of an aerial. Referring to sketch (*b*), which is a polar diagram of the radiation pattern of a transmitter, if A and B are points at which the measured radiated power is half the maximum radiated power from an aerial at the origin O (it is usual to measure this as a voltage; that is, when the voltage is $1/\sqrt{2}$ times the maximum voltage, E_{max}), then the angle AOB is the beamwidth of the aerial.

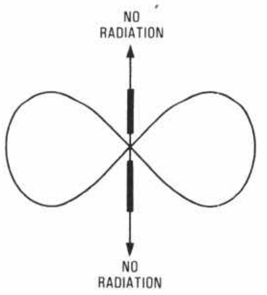


(*b*)

(*c*) The radiation pattern of an aerial is the measurement of the field intensity in 3 dimensions if the aerial were to be placed at the origin. For a vertical half wavelength dipole, the radiation pattern in the horizontal plane is a circle (see sketch (*c*)), while in the vertical plane it is a figure-of-eight (sketch (*d*)).



(*c*)



(*d*)

(*d*) Fading is basically a deterioration of the amplitude of a received signal. When the amplitude of a particular frequency at baseband is reduced, it is termed *selective fading*. If the whole signal fades, it is termed *general fading*.

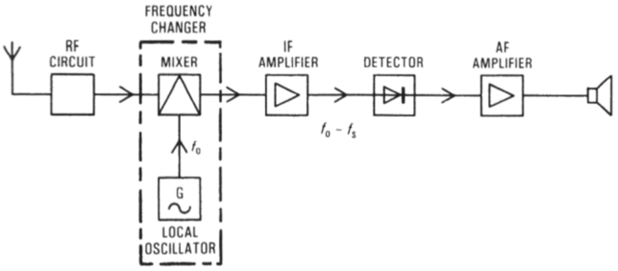
General fading occurs because of continual variations in the state of the ionosphere and can be overcome by automatic gain control (AGC).

Selective fading occurs because of the addition of waves received via 2 paths of different lengths. Fading occurs if the lengths of the 2 paths differ by multiples of half a wavelength. Selective fading is thus nullification of the signal at a particular frequency. Selective fading is more difficult to overcome; it can be overcome by using frequencies nearer to maximum usable frequency (MUF), by using a transmitting aerial which radiates one mode of propagation or by using a system such as Lincompex.

Q6 *Sketch the block diagram of a superheterodyne receiver. Label all the blocks and describe the principle of operation of each for amplitude-modulation sound-broadcast reception.*

State briefly the advantages of a superheterodyne receiver compared with tuned-radio-frequency reception. *(30 min)*

A6 The block diagram is shown in the sketch.



A superheterodyne receiver consists of a radio-frequency (RF) circuit, a frequency changer (consisting of a mixer and local oscillator), an intermediate-frequency (IF) amplifier, a detector, an audio-frequency (AF) amplifier and a loudspeaker.

The input signal to the RF circuit from the aerial consists of all frequencies present at the aerial. It is the function of the RF circuit to suppress all signals other than the one required. Often, an RF amplifier is included in the RF circuit to improve the signal-to-noise ratio of the receiver. The RF circuit also provides a means of effectively coupling the aerial to the receiver in order to extract the maximum RF energy from the aerial.

The output from the RF circuit consists of the required signal frequency (f_s) plus other unwanted frequencies not successfully removed by the RF tuned circuit. These frequencies are all fed to the mixer along with the output from the local oscillator (f_0).

The local oscillator is a variable-frequency oscillator which is ganged to the RF tuned circuit to give a frequency such that when it is combined with the radio frequency a constant-frequency output is produced.

The frequency changer converts the signal frequency, f_s, to the intermediate frequency of the receiver. The output from the frequency changer contains the intermediate frequency ($f_0 - f_s$) plus other frequencies. This signal is fed to the IF amplifier.

The IF amplifier provides most of the gain and selectivity of the receiver and has a gain and bandwidth that remains constant for all values of signal frequency. The output of this stage consists of the intermediate frequency ($f_0 - f_s$), only.

At the detector stage, the audio frequency is extracted from the output of the IF amplifier. It is usually a diode detector, because this type introduces very little distortion. The detector also provides a DC signal proportional to the carrier input which may be used for automatic gain control.

The advantage of a superheterodyne receiver over tuned-radio-frequency (TRF) reception in communications is that it has a well-defined passband characteristic in the IF stages. This gives constant gain and rejection of adjacent channels, whereas TRF receivers cannot provide these characteristics because the tuning capacitor causes changes in the characteristics of the tuned circuit. It is also difficult to provide adjacent-channel selectivity with a TRF receiver.

Q7 *(a) Define the characteristic impedance (Z_0) of a transmission line.*

(b) State which of the primary line coefficients have the greatest influence on the value of characteristic impedance at high frequencies and state an expression for Z_0 in terms of these primary line coefficients.

(c) Determine the distributed inductance of a transmission line 15 km long if the total capacitance of the line is 195 pF and its characteristic impedance is 340 Ω.

(10 min)

A7 (*a*) The characteristic impedance of any transmission line is defined as the input impedance of an infinite length of line.

(*b*) At high frequencies the primary line coefficients which have the greatest influence on the characteristic impedance are the inductance (L) and the capacitance (C) of the line. Inductance is usually measured in millihenrys/kilometres and capacitance in microfarads/kilometre. The characteristic impedance is given by $\sqrt{(L/C)}$.

(*c*) Since $Z_0 = 340\ \Omega$,

$$340 = \sqrt{(L/195 \times 10^{-12})},$$

where L is the inductance in henrys.

$$\therefore \quad L = 340^2 \times 195 \times 10^{-12},$$
$$= 22{\cdot}5 \times 10^{-6}\ \text{H}.$$

The distributed inductance is L/l, where l is the length of the cable.

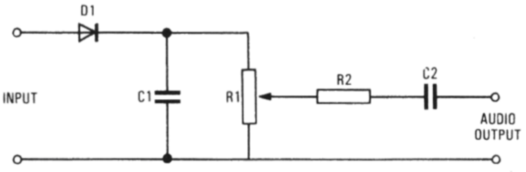
$$\therefore \quad \text{The distributed inductance} = 22{\cdot}5 \times 10^{-6}/15,$$
$$= \underline{1{\cdot}5 \times 10^{-3}\ \text{mH/km}}.$$

Q8 *(a) Draw a diode detector circuit suitable for the demodulation of an amplitude-modulated signal.*

(b) Explain, with reference to waveforms, the operation of the detector circuit, including the reduction of any unwanted signal components produced at the output of the rectifier.

(15 min)

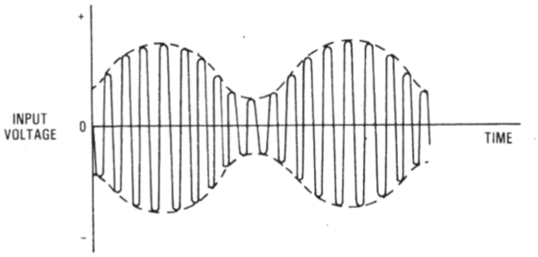
A8 (*a*) Sketch (*a*) shows the circuit required to detect an amplitude-modulated signal.



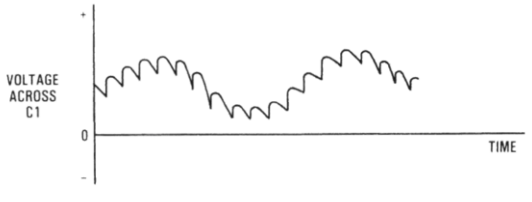
(*a*)

(*b*) If the amplitude-modulated waveform shown in sketch (*b*) is applied to the input of the diode only the positive part of the signal produces pulses of current through the diode because of the characteristics of the diode. As shown in sketch (*c*), these pulses charge capacitor C1 to the peak value at each half cycle. Charging occurs rapidly because the forward resistance of the diode and capacitance of C1 make the time constant small. When the diode is not conducting, capacitor C1 discharges through resistor R1 with a much longer time constant. The signal is thus rectified and smoothed to give the required audio signal superimposed on a direct voltage virtually equal to the amplitude of the unmodulated carrier. A ripple voltage at the carrier frequency is also present.

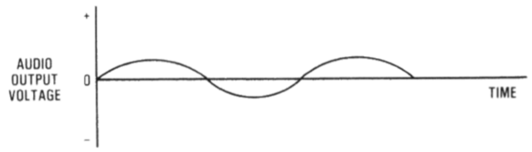
Resistor R2, in conjunction with the input capacitance of the following stage, filters out the ripple voltage, and capacitor C2 blocks the direct component, leaving the required audio signal as the output voltage (see sketch (*d*)).



(*b*)



(*c*)



(*d*)

TEC: RADIO II *(continued)*

Q9 An oscillator is required to tune over the frequency range of 500 Hz–2000 kHz using a coil of self inductance 150 μH. Calculate the maximum and minimum values of the variable tuning capacitor required. (*10 min*)

A9 The oscillator frequency is given by

$$f = \frac{1}{2\pi\sqrt{(LC)}}\ \text{Hz},$$

where L is the inductance in henrys and C is the capacitance in farads.

Rearranging the above expression:

$$C = \frac{1}{4\pi^2 f^2 L}\ \text{F}.$$

For a frequency of 500 Hz, the capacitance required will be

$$\frac{1}{4\pi^2 \times (500)^2 \times 150 \times 10^{-6}} = \frac{10^6}{4\pi^2 \times 25 \times 10^4 \times 150},$$

$$= \underline{675{\cdot}5\ \mu\text{F}.}$$

For a frequency of 2000 kHz the capacitance required will be

$$\frac{1}{4\pi^2 \times (2000)^2 \times 10^6 \times 150 \times 10^{-6}} = \underline{42{\cdot}2\ \text{pF}.}$$

Q10 Define the gain of an aerial. A dipole aerial has to be fed with 50 kW of power to produce a required signal strength in a certain service area. The addition of a reflector element increases the gain by 4 dB. Determine the power reduction as a percentage to produce the same field strength in the service area. (*15 min*)

A10 The gain of an aerial is a measure of its directional property. It is expressed as a logarithmic ratio of power supplied to a simple reference aerial (which could be an isotropic radiator or a dipole aerial) to the power which must be supplied to the directional aerial to obtain the same field strength at a fixed point.

That is, $G = 10 \log_{10} (P_1/P_2)$,

where G is the gain in decibels, P_1 is the power supplied to the reference aerial and P_2 is the power supplied to the aerial under consideration.

Using the expression for the gain:

$$4 = 10 \log_{10} (50/x),$$

where x is the power to be supplied to the modified aerial in kilowatts.

$$\therefore \quad x = 50/\text{antilog}_{10}\, 0{\cdot}4$$
$$= 19{\cdot}90\ \text{kW}.$$

Reduction in power $= 50 - 19{\cdot}9 = 30{\cdot}1$ kW.

Therefore, the percentage reduction in power

$$= \frac{30{\cdot}1}{50} \times 100 = \underline{60{\cdot}2\%}.$$

TEC: TRANSMISSION SYSTEMS II

TEC unit number U81/746. Students are advised to read the notes on page 65

Q1 (*a*) *State the approximate frequency range of normal speech.*
(*b*) *State the approximate frequency range of music.* (*1 min*)

A1 (*a*) 100–10 000 Hz.
(*b*) 20–20 000 Hz.

Q2 (*a*) *List the factors that influence the use of a restricted bandwidth for speech in telecommunications.*
(*b*) *State the bandwidth used for speech in telephone communications.* (*7 min*)

A2 (*a*) (*i*) The average human ear is most sensitive to frequencies in the range 1000–2000 Hz.

(*ii*) Most of the intelligibility of normal speech is in the frequencies below 3400 Hz.

(*iii*) Most of the power generated in normal speech is in the frequency range 400–1000 Hz.

(*iv*) The quality of tone and the individuality of the speaker's voice are reflected in the higher frequencies.

(*v*) The frequency response of the components used in the transmission system is limited.

(*vi*) Multiplexing systems function on the basis of restricted audio bandwidths.

(*vii*) The function of a speech transmission system is to provide an understandable 2-way conversation.

(*b*) The bandwidth used in telephone communications is 300–3400 Hz. This bandwidth provides an understandable speech signal; the loss of speech quality is tolerated on economic and practical grounds.

Q3 Why is it desirable for music to have a greater bandwidth than speech in commercial telecommunications? (*3 min*)

A3 For speech transmissions, it is necessary to transmit only sufficient speech frequencies for the listener to understand the incoming speech signals. For music transmissions, it is necessary to transmit as many of the music frequencies that were originally produced as possible, so that the listener's enjoyment of the music is not impaired. This requires a wider bandwidth than is necessary for commercial speech transmission.

Q4 What is the bandwidth of a telegraph transmission channel? (*½ min*)

A4 120 Hz.

Q5 Does a baseband signal normally contain all the frequencies generated by the original source? (*½ min*)

A5 No.

Q6 The frequency range of the baseband signal for high-quality music transmission should be. . . . . (Select the correct answer from the following list.) (*½ min*)

(*a*) *0–10 000 Hz.*
(*b*) *50–10 000 Hz.*
(*c*) *300–10 000 Hz.*

A6 (*b*) 50–10 000 Hz.

Q7 If it is assumed that ideal transmission conditions exist, why is there some loss in picture quality in video transmissions? (*1 min*)

A7 Some of the quality of the picture is lost because a restricted bandwidth is used.

Q8 What is the bandwidth of a speech channel in a line transmission system? (*½ min*)

A8 4 kHz.

Q9 State the bandwidths of

(*a*) *a 625-line black-and-white video transmission system, and*
(*b*) *a 625-line colour video transmission system.*

(*½ min*)

A9 Both systems have a bandwidth of 5·5 MHz.

Q10 *What condition is referred to by the terms "resistor", "shot", "partition", "static", "galactic", and "flicker" in a line or radio transmission system.* (½ *min*)

A10 They are all noise conditions.

Q11 *Define the term "baseband".* (*3 min*)

A11 *Baseband* is the collective term given to all the original frequencies that must be transmitted within a transmission system in order for an intelligible signal to be produced at the receiving end.

For example, 300–3400 Hz for telephony, and 0–5·5 MHz for video transmission.

Q12 *Briefly explain the term "signal attenuation".* (*2 min*)

A12 A signal propagating along a transmission line is weakened by the inherent resistive and reactive parameters of the line. This weakening of signal strength is referred to as *signal attenuation.*

Q13 *What is the basic function of a line amplifier?* (*2 min*)

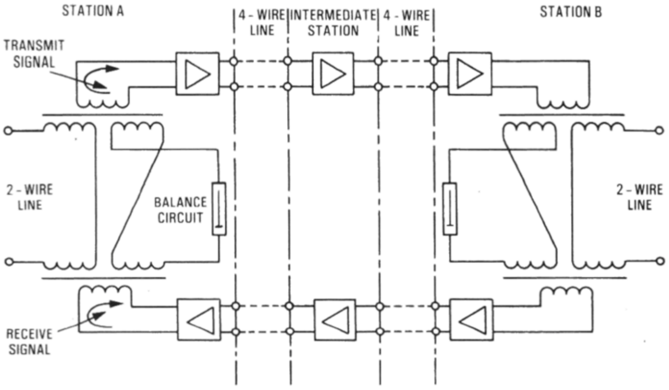
A13 The basic function of a line amplifier is to increase the strength of an attenuated signal.

Q14 *What basic restriction does an amplifier place on a 2-wire line transmission system?* (*2 min*)

A14 Amplifiers are unidrectional devices; therefore, when they are connected into a 2-wire system, communication is possible only in one direction.

Q15 *Sketch a typical 2-wire-to-4-wire transmission link and explain how howling might occur in the system.* (*12 min*)

A15



If, for example, the impedance of the 2-wire circuit is considerably less than the balance circuit, then the induced currents in the 2-wire and balance circuits, owing to the receive signal, are not equal. This inequality results in the receive signal being transferred not only to the 2-wire circuit, but also to the transmit coil of the 4-wire unit. If the signal that is transferred to the transmit coil is of sufficiently high level, then oscillations can occur in the 4-wire line circuit. These oscillations are referred to as *howling.*

Q16 *What is meant by the term "noise" in the context of transmission systems?* (*2 min*)

A16 Noise in a transmission system is any unwanted electrical energy that is present in the system.

Q17 *State a typical signal-to-noise ratio (in decibels) of a telephone link.* (½ *min*)

A17 A typical signal-to-noise ratio of a telephone link is in the range 35–40 dB.

Q18 *The overall power gain between the 2-wire sides of a 2-wire-to-4-wire transmission system is . . . . (Select the correct answer from the following list.)*

(*a*) *20.*

(*b*) *10.*

(*c*) *1.*

(*d*) *less than unity.*

(½ *min*)

A18 (*d*) less than unity.

Q19 *When does maximum imbalance occur in a 2-wire-to-4-wire terminating unit?* (*1 min*)

A19 Maximum imbalance occurs when the 2-wire circuit is open-circuited or short-circuited at the terminals of the unit.

Q20 *Line amplifiers are normally required if the length of the line exceeds. . . . . (Select the correct answer from the following list.)*

(*a*) *10 km.*

(*b*) *20 km.*

(*c*) *30 km.*

(½ *min*)

A20 (*c*) 30 km.

Q21 *What undesirable feature occurs in a line transmission system if*

(*a*) *a single high-gain amplifier is positioned at the sending terminal, and*

(*b*) *a single high-gain amplifier is positioned at the receiving terminal?* (*3 min*)

A21 (*a*) The strength of the signal at the output of the amplifier would cause interference to adjacent transmission paths.

(*b*) The signal-to-noise ratio at the input may be so low that an unintelligible signal would be produced at the amplifier's output.

Q22 *What technique is used to enable a single transmission path to carry simultaneously a number of similar baseband signals.* (½ *min*)

A22 Multiplexing.

Q23 *Complete the following statement.*

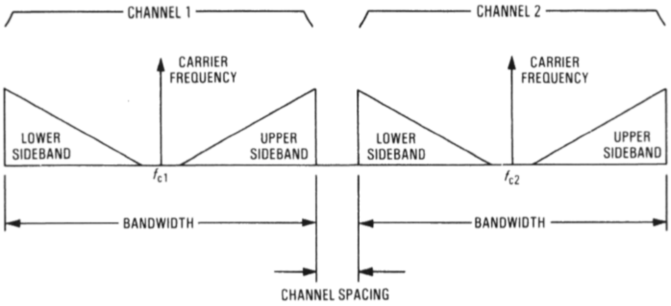
The standard basic CCITT† *transmission group, as used in the UK, has (a). . . . . channels, and a supergroup contains (b). . . . . . . basic groups.* (½ *min*)

A23 (*a*) 12 channels.

(*b*) 5 basic groups.

Q24 *Draw and label a typical frequency-domain diagram of a system where 2 similar audio baseband signals are transmitted over a common transmission path.* (*5 min*)

A24



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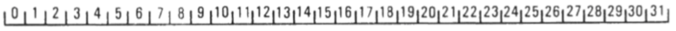
† *International Telegraph and Telephone Consultative Committee*

Q25 The sketch shows one frame of a 30-channel time-division multiplex system.

- *(a) Which channel time slots are used as voice channels?*
- *(b) What is the time duration of one channel time slot?*
- *(c) Which time slot contains the alarm indication facility?*

(2 min)



A25 (*a*) 1–15 and 17–31.

(*b*) $3{\cdot}9\ \mu s$.

(*c*) Time slot 0.

Q26 Define the term "modulation". *(2 min)*

A26 *Modulation* is the process of changing the characteristics of a high-frequency signal in such a manner as to enable low-frequency information signals to be carried by the high-frequency signal.

Q27 How many digit time slots are there in each channel time slot of a 30-channel pulse-code modulation system? *(½ min)*

A27 8.

Q28 A hypergroup in a frequency-division multiplex system comprises, typically,.............. (Select the correct answer from the following list.)

- *(a) 15 supergroups.*
- *(b) 24 supergroups.*
- *(c) 32 supergroups.*

(½ min)

A28 (*a*) 15 supergroups.

[*Tutorial note:* The hypergroup of a 4 MHz system consists of 16 supergroups, whereas each hypergroup on a 12 MHz system consists of only 15 supergroups.]

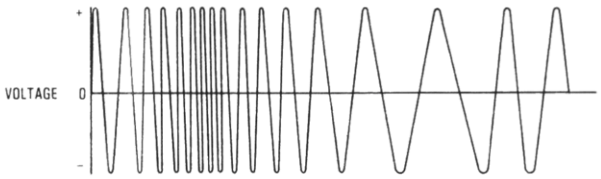
Q29 Which of the following modulation methods can be used in time-division multiplex systems:

- *(a) amplitude modulation,*
- *(b) pulse-code modulation,*
- *(c) phase modulation,*
- *(d) pulse-amplitude modulation, or*
- *(e) frequency modulation?*

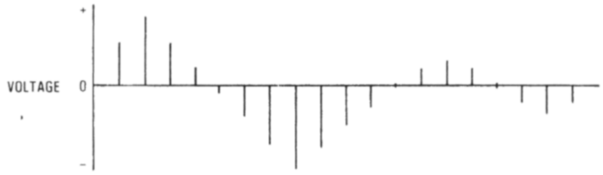
(1 min)

A29 (*b*) and (*d*).

Q30 Which modulation methods do each of the following waveforms represent? *(1 min)*



(*a*)



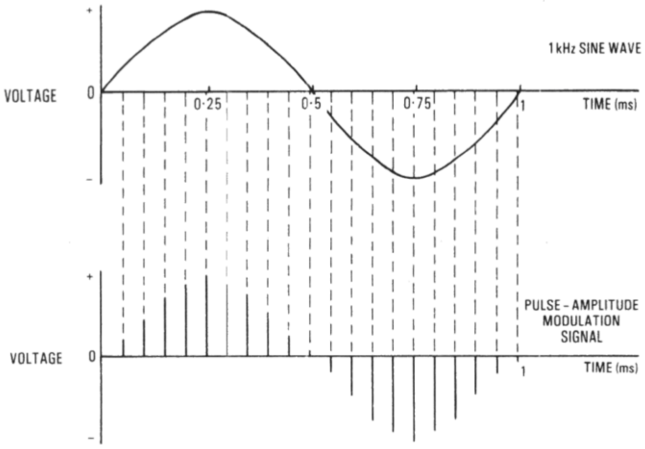
(*b*)

A30 (*a*) Frequency modulation.

(*b*) Pulse-amplitude modulation.

Q31 A pure sine wave of 1000 Hz is pulse-amplitude modulated; the sampling rate is 20 000 samples/s. Sketch a typical waveform showing one cycle of the resulting signal. *(5 min)*

A31



[*Tutorial note:* The period of the sine wave is 1 ms; therefore, 20 samples are taken of each cycle.]

Q32 Compare equivalent time-division multiplex (TDM) and frequency-division multiplex (FDM) systems by completing each of the following sentences.

- *(a) A..............system is cheaper to provide.*
- *(b) A..............system requires a greater bandwidth.*
- *(c) A..............system is less noisy.*
- *(d) A..............system has greater reliability.*

(1 min)

A32 (*a*) TDM

(*b*) TDM

(*c*) TDM

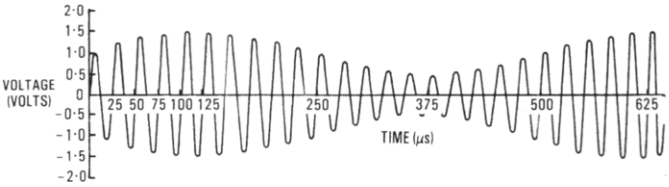
(*d*) FDM

[*Tutorial note:* A TDM system has more electronic components than a comparable FDM system and, therefore, is less reliable.]

Q33 Consider the waveform shown in the sketch and complete the following.

- *(a) Identify the wave form,*
- *(b) determine the carrier frequency,*
- *(c) determine the modulating frequency, and*
- *(d) determine the percentage modulation.*

(5 min)



A33 (*a*) Amplitude-modulated waveform.

(*b*) The carrier frequency $= \dfrac{1}{25 \times 10^{-6}} = 40$ kHz.

(*c*) The modulating frequency $= \dfrac{1}{500 \times 10^{-6}} = 2000$ Hz.

(*d*) The percentage modulation $= \dfrac{0{\cdot}5}{1{\cdot}0} \times 100 = 50\%$.

[*Tutorial note:* If A_c is the amplitude of the unmodulated carrier and A_d is the maximum deviation of the amplitude of the modulated carrier, then the percentage modulation is given by

$$\frac{A_d}{A_c} \times 100\%]$$

Q34 Why are single-sideband systems preferred to double-sideband systems? (*1 min*)

A34 Single-sideband systems have a narrower bandwidth and require less power than double-sideband systems.

Q35 What terms are used to describe

(a) the condition where the modulation percentage of an amplitude modulated wave exceeds 100%, and

(b) the recovery of the modulating signal from the modulated signal. (*1 min*)

A35 (*a*) Overmodulation.

(*b*) Demodulation.

Q36 A carrier wave of 1 MHz is frequency modulated by a 20 kHz signal. When the modulating frequency is at its maximum positive amplitude, the frequency of the carrier is 1·1 MHz. Determine

(a) the modulation index, and

(b) the frequency swing.

(*3 min*)

A36 (*a*) Modulation index $= \dfrac{\text{frequency deviation}}{\text{modulating frequency}}$,

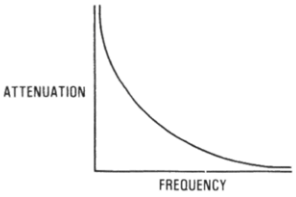
$$= \frac{100 \times 10^3}{20 \times 10^3},$$

$$= \underline{5.}$$

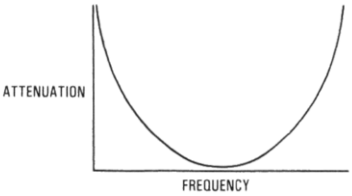
(*b*) Frequency swing = 2 × frequency deviation,

$$= \underline{200 \text{ kHz.}}$$

Q37 Identify the types of filter used to obtain the frequency responses shown in the following sketches. (*1 min*)



(*a*)



(*b*)

A37 (*a*) High-pass filter.

(*b*) Band-pass filter.

Q38 Complete the following statement.
For equivalent systems, the bandwidth of an amplitude modulation (AM) system is (a)............. than that of a frequency modulation (FM) system, the power required by an FM system is (b)............. than that of an AM system, and the signal-to-noise ratio of an FM system is generally (c)............. than that of an AM system. (*1 min*)

A38 (*a*) narrower

(*b*) less

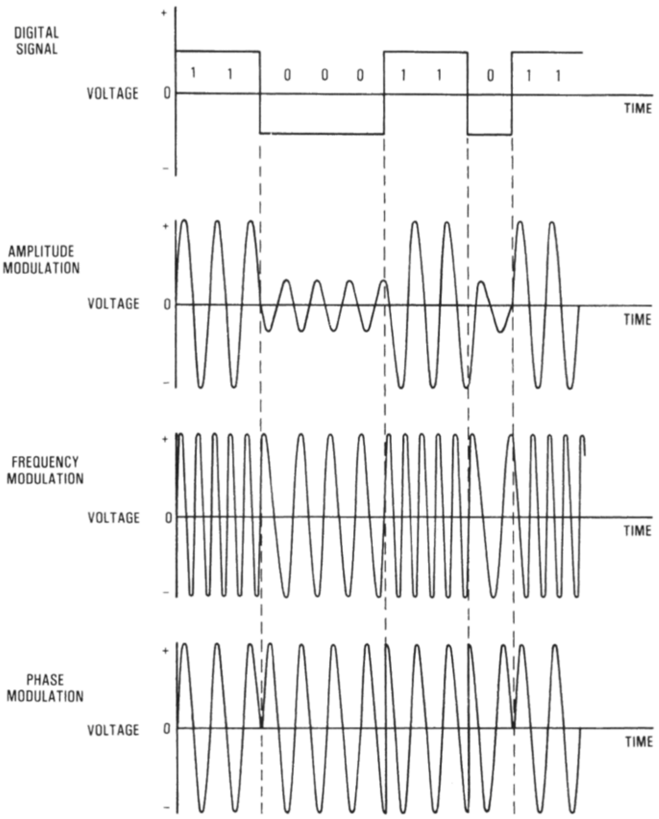
(*c*) better or higher

Q39 What is the minimum sampling rate required for a pulse-amplitude modulation system that has a baseband in the frequency range 50–10 000 Hz? (*1 min*)

A39 20 000 samples/s.
[*Tutorial note:* The minimum sampling rate is twice the highest frequency in the baseband.]

Q40 Sketch basic waveforms to illustrate how digital signals can be represented in amplitude modulation, frequency modulation and phase modulation systems. (*5 min*)

A40



Q41 Explain the basic concept of converting a pulse-amplitude modulation signal to a pulse-code modulation signal. (*6 min*)

A41 In pulse-amplitude modulation (PAM) systems the voltage level of the analogue signal is sampled at regular intervals. No 2 sampled levels are necessarily identical, and the number of differing voltage values is infinite. In pulse-code modulation (PCM) a voltage level is represented by an 8-bit binary code. As the number of variations in an 8-bit code is limited, the number of possible coded voltage levels is also limited. Thus, in PCM only a discrete number of voltage levels can be transmitted to line.

To convert a PAM signal to a PCM signal the sampled voltage is compared with all the PCM voltage levels. The sampled voltage level is rounded up or rounded down to the nearest PCM voltage level and the binary code corresponding to this voltage level is transmitted to line. The process of rounding up or rounding down is known as *quantisation*, and the 8-bit code contains not only the voltage level, but also the polarity of the voltage (positive or negative).

Q42 If a 60 kHz carrier is amplitude modulated by a 2280 Hz sinusoidal signal, what frequencies are present in the modulated carrier? (*1 min*)

A42 60 kHz, 57·72 kHz and 62·28 kHz.

Q43 Which frequency is modulated in a transmission system,

(a) the carrier frequency, or

(b) the baseband frequency?

(Select the correct answer.) ($\frac{1}{2}$ *min*)

A43 (*a*)

Q44 Are carrier frequencies ALWAYS *higher than their associated baseband frequencies?* ($\frac{1}{2}$ *min*)

A44 Yes.

Q45 Complete the following statement.
In frequency modulation the frequency deviation is proportional to the peak amplitude of the (a)..............signal and is independent of the (b)..............frequency. ($\frac{1}{2}$ *min*)

A45 (*a*) modulating
(*b*) modulating

Q46 What components in a telephone network impede the transmission of digital signals? ($\frac{1}{2}$ *min*)

A46 Transmission bridges, line amplifiers and frequency-division multiplex systems.

Q47 A frequency modulation system has a carrier frequency of 1 MHz. The modulating frequency is 30 kHz and the bandwidth is to be restricted to 200 kHz. Determine the maximum frequency deviation of the system. (*3 min*)

A47 If B is the bandwidth, f_{dev} is the frequency deviation, and f_{m} is the modulating frequency, then

$$B = 2(f_{\mathrm{dev}} + f_{\mathrm{m}}).$$

$$\therefore \quad f_{\mathrm{dev}} = \frac{B}{2} - f_{\mathrm{m}},$$

$$= \underline{70\ \mathrm{kHz}.}$$

Q48 State the basic advantage of using logarithmic based units in the calculation of transmission losses and gains. ($\frac{1}{2}$ *min*)

A48 Simplicity of mathematical calculations.

Q49 Determine the gain (in decibels) of an amplifier which has an input current of 20 μA and an output current of 1 mA. (*2 min*)

A49

$$\text{Current gain} = 20 \log_{10} \frac{1 \times 10^{-3}}{20 \times 10^{-6}},$$

$$= 20 \log_{10} 50,$$

$$= \underline{34\ \mathrm{dB}.}$$

Q50 Determine the signal-to-noise ratio (in decibels) of a system which has an output noise power of 0·5 mW and an output signal power of 2 W. (*2 min*)

A50 The signal-to-noise ratio $= 10 \log_{10} \dfrac{\text{signal power}}{\text{noise power}}$,

$$= 10 \log_{10} \frac{2}{0 \cdot 5 \times 10^{-3}},$$

$$= 10 \log_{10} 4000,$$

$$= \underline{36\ \mathrm{dB}.}$$

Q51 Define the bel, state its limitations and how these limitations are overcome. (*3 min*)

A51 The bel is a unit used to compare 2 amounts of power. To obtain the power ratio in bels the logarithm of the power ratio is taken.

Thus, the power ratio expressed in bels
$= \log_{10}$ (power ratio).

The bel is too large a unit to be used under normal working conditions; to overcome this the decibel is used, which is one tenth of a bel.

Q52 Determine the absolute power level, referred to 1 mW, of a signal of 35 mW. (*2 min*)

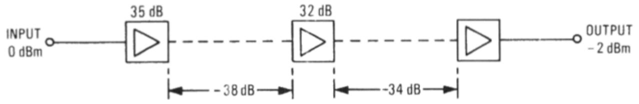
A52 Absolute power $= 10 \log_{10} \dfrac{35}{1} = \underline{15 \cdot 44\ \mathrm{dBm}.}$

Q53 Determine the absolute power level, referred to 1 mW, of a signal of 0·2 mW. (*2 min*)

A53 Absolute power $= 10 \log_{10} \dfrac{0 \cdot 2}{1} = \underline{-7\ \mathrm{dBm}.}$

[*Tutorial note:* The negative sign signifies a power of less than 1 mW.]

Q54 The sketch shows the gains and losses of a transmission line. Determine the power ratio, in decibels, of the final amplifier. (*2 min*)



A54 The total gain of the first 2 amplifiers

$$= 35 + 32 = 67\ \mathrm{dB}.$$

The total attenuation of the line

$$= 38 + 34 = 72\ \mathrm{dB}.$$

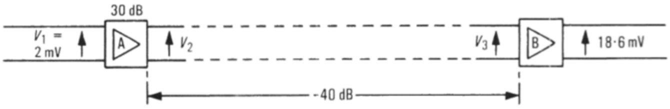
The total loss of the system up to the input of the third amplifier

$$= 72 - 67 = 5\ \mathrm{dB}.$$

The overall loss of the system is 2 dB; therefore, the gain of the final amplifier

$$= 5 - 2 = \underline{3\ \mathrm{dB}.}$$

Q55 For the system shown in the sketch, determine the values of
(*a*) *V_2,*
(*b*) *V_3, and*
(*c*) *the gain of amplifier B.* (*8 min*)



A55 (*a*) By expressing the gain of amplifier A (decibels) in terms of V_1 and V_2,

$$30 = 20 \log_{10} \frac{V_2}{V_1}.$$

$$\therefore \quad 1 \cdot 5 = \log_{10} \frac{V_2}{V_1},$$

$$= \log_{10} V_2 - \log_{10} V_1,$$

$$= \log_{10} V_2 - 0 \cdot 3.$$

$$\therefore \quad 1 \cdot 8 = \log_{10} V_2.$$

$$\therefore \quad V_2 = \text{antilog}_{10}\, 1 \cdot 8$$

$$= \underline{63\ \mathrm{mV}.}$$

(*b*) Similarly, for the transmission line,

$$-40 = 20 \log_{10} \frac{V_3}{V_2}.$$

$$\therefore \quad -2 = \log_{10} V_3 - \log_{10} 63,$$

$$= \log_{10} V_3 - 1 \cdot 8.$$

$$\therefore \quad -0 \cdot 2 = \log_{10} V_3.$$

$$\therefore \quad V_3 = \text{antilog}_{10}\, \bar{1} \cdot 8,$$

$$= \underline{0 \cdot 63\ \mathrm{mV}.}$$

(*c*) The gain of amplifier B

$$= 20 \log_{10} \frac{18 \cdot 6}{0 \cdot 63},$$

$$= 20 \log_{10} 29 \cdot 5,$$

$$= 20 \times 1 \cdot 47,$$

$$= \underline{29 \cdot 4\ \mathrm{dB}.}$$

Q56 Determine the frequency of a carrier which has a wavelength of 250 m. (*2 min*)

A56

$$\text{Frequency} = \frac{\text{speed of light}}{\text{wavelength}},$$

$$= \frac{3 \times 10^8}{250},$$

$$= 1{\cdot}2 \times 10^6,$$

$$= \underline{1{\cdot}2\ \text{MHz.}}$$

Q57 Is the speed of light in an optical fibre the same as the speed of light in free space? ($\frac{1}{2}$ *min*)

A57 No.
[*Tutorial note:* All transmission lines inhibit the speed of the signal propagating along them. The speed of light along an optical fibre is of the order of 2×10^8 m/s.]

Q58 Determine the length of the transmitting aerial of a radio transmission system, if the frequency of the carrier is 25 MHz and the aerial is one quarter of a wavelength. (*2 min*)

A58 The wavelength of transmission

$$= \frac{\text{speed of light}}{\text{frequency}},$$

$$= \frac{3 \times 10^8}{25 \times 10^6},$$

$$= \underline{12\ \text{m.}}$$

Therefore, the length of the aerial is 12/4 = $\underline{3\ \text{m.}}$

Q59 A telephone transmission system is required to transmit a minimum of 10 channels over the band 12–64 kHz. State whether an amplitude-modulated or frequency-modulated system would be suitable, and give reasons for your answer. (*5 min*)

A59 To cater for a minimum of 10 channels, a maximum channel bandwidth of 5·2 kHz is available. The bandwidth of a telephone baseband signal is 3·1 kHz. The bandwidth of a channel in a frequency-modulated (FM) system is always several times greater than the bandwidth of the baseband signal; therefore, an FM system is not suitable in this case.

The channel bandwidth required for a double-sideband amplitude modulation (AM) system is 6·8 kHz; therefore, only 7 channels are available. The channel bandwidth required for a single-sideband AM system is at least 3·1 kHz, and in practice is made to be 4 kHz to cater for channel spacing. The number of 4 kHz channels that can be catered for in a system transmitting over the band 12–64 kHz is given by

$$\frac{64 - 12}{4} = 13.$$

Therefore, a suitable transmission system is a single-sideband AM system, with or without the carrier suppressed.

Q60 Determine the power in the side frequencies of an amplitude-modulated wave which has a total power of 2 kW and a modulation depth of 75%. (*4 min*)

A60 The total power developed by the amplitude-modulated wave is given by

$$P_c\left(1 + \frac{m^2}{2}\right),$$

where P_c is the power developed by the carrier and m is the modulation factor (0·75).

$$\therefore \quad P_c = \frac{2000}{\left(1 + \frac{m^2}{2}\right)} = \frac{2000}{1{\cdot}281} = 1561\ \text{W}.$$

Therefore, the power developed by the side frequencies

$$= 2000 - 1561 = \underline{439\ \text{W.}}$$

N. C. Webber

TEC: TELEPHONE SWITCHING SYSTEMS III

TEC unit number U81/741. Students are advised to read the notes on page 65.

Q1 Which TWO *of the following statements correctly describe traffic intensity, in erlangs, during a specified period of time?*

(*a*) *The average number of calls occurring in the specified period,*

(*b*) *the total number of calls occurring in the specified period,*

(*c*) *the average number of simultaneous calls occurring in the specified period,*

(*d*) *the total number of calls occurring in the specified period divided by their average holding time,*

(*e*) *the number of calls that originate during a period equal to the average holding time of the calls occurring in the specified period, or*

(*f*) *the proportion of the specified period for which a circuit is free.* (*2 min*)

A1 (*c*) and (*e*).

Q2 A group of 3 sequentially-tested trunks is offered 1E of traffic. Each trunk carries traffic as follows: trunk 1—0·5 E; trunk 2—0·3 E; and trunk 3—0·06 E.

(*a*) *How much traffic is lost?*

(*b*) *What is the grade of service?*

(*c*) *How would the answers to* (*a*) *and* (*b*) *be modified if trunk 2 was busied against traffic?* (*5 min*)

A2 (*a*) Traffic lost = traffic offered—traffic carried,

$$= 1 - (0{\cdot}5 + 0{\cdot}3 + 0{\cdot}06),$$

$$= \underline{0{\cdot}14\ \text{E.}}$$

(*b*) Grade of service $= \frac{\text{lost traffic}}{\text{traffic offered}},$

$$= \frac{0{\cdot}14}{1},$$

$$= \underline{0{\cdot}14.}$$

(*c*) If trunk 2 is busied against traffic, then the traffic that was carried by this trunk is now carried by trunk 3. The traffic previously carried by trunk 3 is now lost.

Therefore, traffic lost = 1 − (0·5 + 0·3),

$$= 0{\cdot}2\ \text{E}.$$

The grade of service falls from 0·14 to 0·2.

Q3 If a telephone exchange consists of 3 switching stages having grades of service of 0·005, 0·005 and 0·02, respectively, what is the approximate overall grade of service of the exchange. State the conditions necessary for your answer to be a good approximation. (*4 min*)

A3 The overall grade of service is approximately equal to the sum of the grades of service of each stage.

Therefore, the overall grade of service

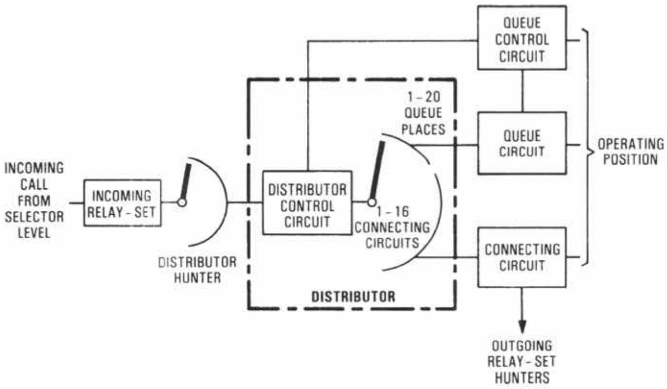
$$\approx 0{\cdot}005 + 0{\cdot}005 + 0{\cdot}02,$$

$$= \underline{0{\cdot}03.}$$

The approximation is good provided that the number of switching stages is small (that is, ≤ 3) and each stage has a low grade of service (that is, $\leq 0{\cdot}02$).
[*Tutorial note:* In practice, the sum of the individual grades of service is accurate to within approximately 2%, for a grade of service of 0·02 at 3 successive stages, and 3%, for a grade of service of 0·033 at 3 successive stages.]

Q4 Draw a fully-labelled block diagram showing the trunking arrangements of a main queue of a cordless switchboard. (*5 min*)

A4



Q5 Discuss the advantages of the call-queueing system of a cordless switchboard as compared to the random servicing of calls by an operator. (*5 min*)

A5 Incoming calls entering a queue are served on a first-come first-served basis; the operator has no choice of which call to select, and must deal with the call that is at the head of the queue. This method is much fairer than random servicing, where the operator selects which call to answer irrespective of the order in which calls arrive. During busy periods it is possible for a call to be overlooked and for the caller to experience an unacceptable delay before the call is answered.

Q6 Distinguish between inband and outband signalling systems. (*7 min*)

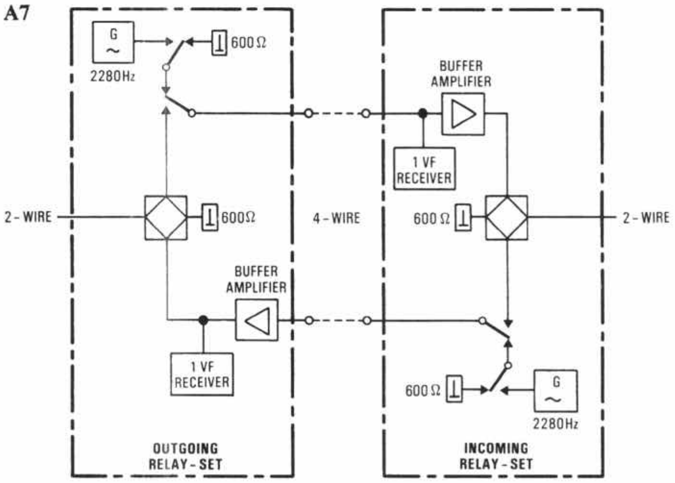
A6 Both systems are AC signalling systems. The AC signals of inband signalling systems are transmitted within the same frequency band as the speech signals; that is, in the frequency range 300–3400 Hz.

Although the internationally agreed standards for telephone speech transmission provide for a speech bandwidth of 3·1 kHz (300–3400 Hz), each speech channel of a frequency-division multiplex system is allocated a bandwidth of 4 kHz. In outband signalling systems the channel band below 3400 Hz is devoted solely to speech, and the remainder of the 4 kHz channel bandwidth (3400–4000 Hz) is used for signalling frequencies.

[*Tutorial Note:* Typical systems are Signalling System AC No. 9 (SSAC9), which uses a signalling frequency of 2280 Hz (inband); and SSAC8, which uses a signalling frequency of 3825 Hz (outband).]

Q7 If 2 telephone exchanges are directly connected by a 4-wire junction using Signalling System AC No. 9 (SSAC9), draw a block schematic diagram showing the positions of all the necessary signalling components. Your diagram should include line terminating units, voice-frequency receivers, buffer amplifiers and 2280 Hz tone generators. (*5 min*)

A7



Q8 Complete the following table, which describes Signalling System AC No. 9 (SSAC9).

Direction	*Function of Signal*	*Duration of Line Signal (ms)*
Forward		65
	Dial pulses	
Backward		250
	Calling subscriber clears	
·	*Called subscriber clears*	

A8

Direction	Function of Signal	Duration of Line Signal (ms)
Forward	Seizure of distant selector	65
Forward	Dial Pulses	57 (for each break period)
Backward	Called subscriber answer	250
Forward	Calling subscriber clears	900
Backward	Called subscriber clears	250

Q9 State 3 reasons for the introduction of high-speed signalling systems. (*5 min*)

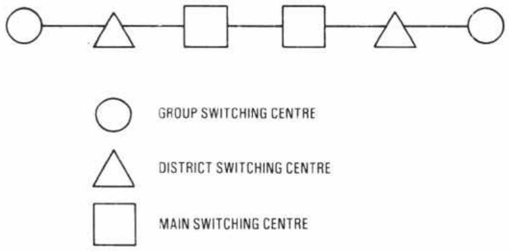
A9 The 3 main reasons for the introduction of high-speed signalling systems are

(*a*) to limit post-dialling delay;

(*b*) to make more efficient use of trunk circuits, exchange common-control equipment and line signalling equipment; and

(*c*) to take advantage of the rapid transfer of information made possible by press-button telephones, repertory diallers, etc.

Q10 Describe the signalling procedure for the setting up of a call via the transit network for the arrangement of exchanges shown in the sketch; assume that Signalling System Multi-Frequency No. 2 (SSMF2) is used. (*10 min*)



A10 The outgoing relay-set in the originating group switching centre (GSC) sends a *seizure* signal forward to the district switching centre (DSC).

At the DSC the incoming relay-set seizes a free transit register and a *backward-prefix* signal is returned to the controlling GSC. On receipt of this signal, the multi-frequency (MF) equipment associated with the controlling register sends a *forward-prefix* signal in acknowledgement.

After the *forward-prefix signal* has been received at the DSC, the *backward-prefix* signal is replaced by an 80 ms pulse of *transit-proceed-to-send* signal, which, in turn, causes the cessation of the *forward-prefix* signal from the controlling register and the application of the A-, B- and C-routeing digits.

[*Tutorial Note:* The exchange of signals is by compelled signalling; that is, the signals persist until acknowledged. All the signals that follow the initial prefixes are pulse controlled, each pulse being 80 ms in duration and preceded by a *prefix* signal.]

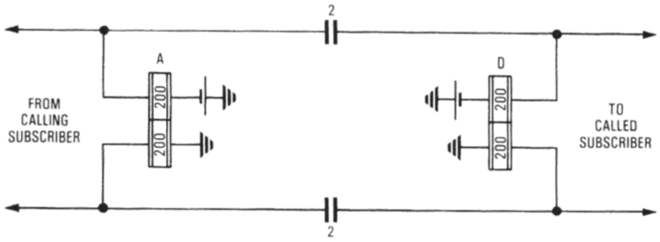
After the DSC register-translator has translated the code digits, it initiates a *seizure-demand* signal to the required main switching centre (MSC), which then returns a compelled *backward-prefix* signal to the originating GSC. The GSC sends a compelled *forward-prefix* signal to the MSC, which responds with a *transit-proceed-to-send* signal. The

A-, B- and C-digits, in pulse-signal form, are sent forward to the MSC to be translated and used to select the route to the next switching stage.

The interchange of signals between the originating GSC and each successive transit switching centre continues until the final GSC is reached. From this a *terminal-proceed-to-send* signal is returned and the C-digit (B-digit on calls to London) is transmitted as an 80 ms pulse. Each subsequent digit, up to and including the J-digit, is transmitted as an 80 ms pulse on receipt of further *terminal-proceed-to-send* signals. When the last expected signal has been received and stored in the incoming register, a *number-received* signal is returned.

Q11 Sketch a simple labelled diagram of a capacitor-type transmission bridge. (*4 min*)

A11



Q12 State whether each of the following statements is true or false, and explain the reason for your answer in each case.

(*a*) *A capacitor-type transmission bridge acts as a low-pass filter.*

(*b*) *One of the functions of any transmission bridge is to supply DC to the subscribers' telephones.*

(*c*) *The relays used in both capacitor- and transformer-type transmission bridges must be high-impedance relays.*

(*d*) *Longitudinal current surges are eliminated by a transformer-type transmission bridge.*

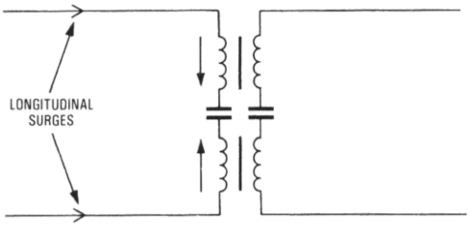
(*12 min*)

A12 (*a*) False. At low frequencies the relay coils present a low impedance, and their impedance increases as the frequency increases. As a result, the shunting effect of the relays is greater in the lower range of frequencies. Also, the impedance of the series capacitors is high at low frequencies. Thus, the loss through the bridge is high at low frequencies, and the bridge acts as a high-pass filter.

(*b*) True. The transmission bridge supplies DC via the subscriber's line to the subscriber's telephone to energise the telephone circuit.

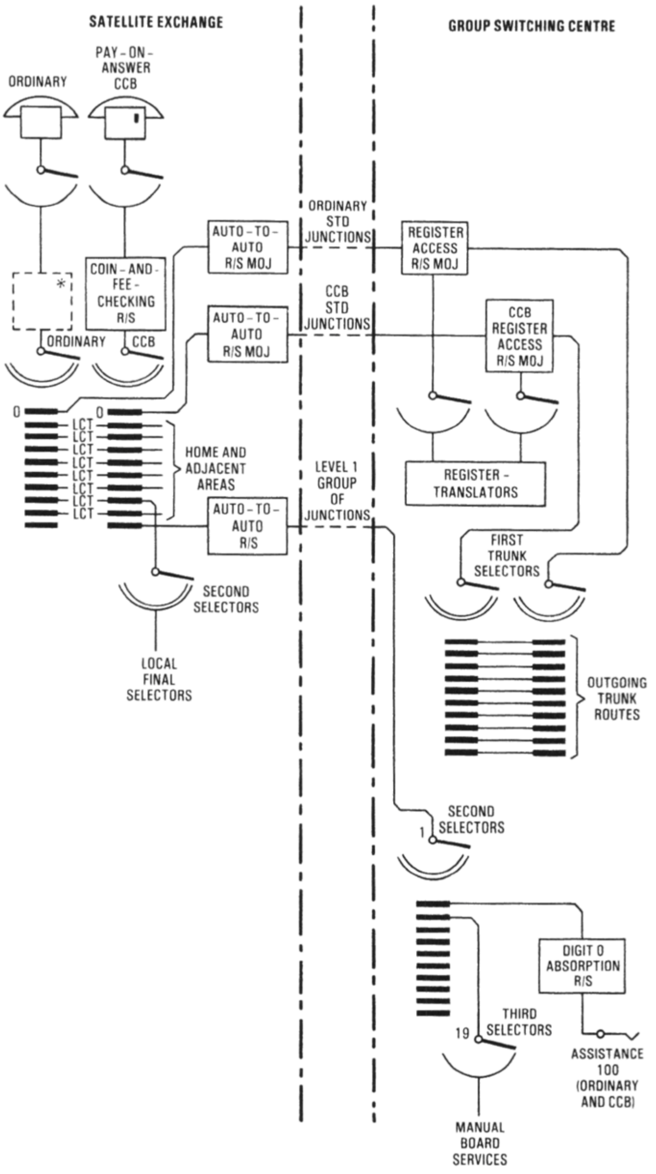
(*c*) False. The relays in a capacitor-type transmission bridge are connected across the speech path and must, therefore, be high impedance, to minimise the shunting of AC signals. However, in a transformer-type transmission bridge the relays are in series with the speech path and, therefore, must be low-impedance relays.

(*d*) True. Longitudinal surges are current surges which flow in the same direction in the positive and negative legs of the line. The surges pass through the windings of the bridge transformer in such a direction that no EMF is induced into the secondary circuit (see sketch).



Q13 Sketch a trunking diagram showing how ordinary, business and pay-on-answer coinbox lines on a non-director satellite exchange gain access to local subscribers' lines, local outgoing junctions, subscriber trunk dialling (STD) junctions and manual board services. Indicate on your diagram the position of coin-and-fee-checking, local-call-timing and auto-to-auto relay-sets, together with the necessary STD relay-sets. (*10 min*)

A13



CCB: coin-collecting box
LCT: local call timer
MOJ: metering over junction
R/S: relay-set
STD: subscriber trunk dialling
* Alternative position for LCT

Q14 State which item of equipment in a Strowger director exchange performs each of the following functions:

(*a*) *responds to the first translated routeing digit,*

(*b*) *responds to the first digit dialled by the subscriber,*

(*c*) *contains a transmission bridge for the calling subscriber,*

(*d*) *responds to the second and third digits dialled by the subscriber,*

(*e*) *returns dial tone to the calling subscriber, and*

(*f*) *routes a subscriber trunk dialling (STD) call through to the STD equipment.*

(*3 min*)

A14 (*a*) First code selector.

(*b*) A-digit selector.

(*c*) First code selector.

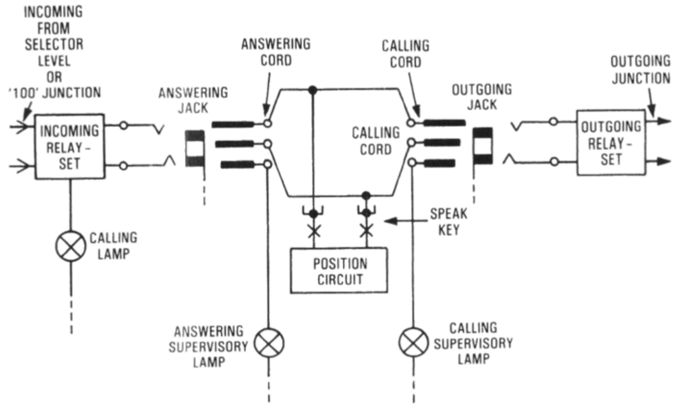
(*d*) BC switch in the director.

(*e*) A-digit selector.

(*f*) Local register.

Q15 Describe, with the aid of a diagram, how an assistance call is connected from an incoming relay-set, via a cord circuit, to an outgoing relay-set. *(15 min)*

A15 The sketch shows a block schematic of the cord circuit. An incoming call seizes the incoming relay-set, which causes the calling lamp on the switchboard to light. The operator answers the call by inserting an answering cord into the answering jack associated with the calling lamp and then by operating the cord circuit SPEAK key. This connects the position circuit to the answering cord. The operator can then speak to the caller and determine the caller's requirements.



The operator then selects an appropriate free outgoing jack associated with the required outgoing route and inserts the calling cord. After dialling the necessary information digits, the operator checks that the correct supervisory tone is returned, and then releases the SPEAK key. This leaves the incoming and outgoing relay-sets interconnected by the cord circuit.

[*Tutorial Note:* Speech transmission occurs over the tip and ring of the cord circuit, and all the supervisory conditions are applied over the sleeve circuit; hence, the name *sleeve control.*]

Q16 Give 3 advantages that the cordless switchboard has over the sleeve-control type. *(5 min)*

A16 [*Tutorial Note:* Any 3 items from the following list could be given.]

(*a*) The operator's position is designed in the form of an office desk and can be installed in office-type accommodation. The units can be grouped to take full advantage of natural lighting from windows, and the absence of cords removes a major source of noise. Overall, operators are given a much quieter and more pleasant environment in which to work.

(*b*) Call queueing is used, enabling an improved service to be given to customers. [*Tutorial Note:* See answer to Q5.]

(*c*) The operators' positions can be separate from the associated switching equipment, and, if required, can be located in different buildings.

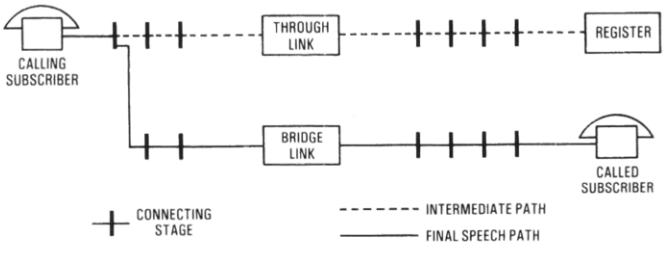
(*d*) The speech path is set up via automatic equipment instead of cord circuits; this reduces the fault liability.

Q17 Describe, briefly, the stored-program method of control that is used in a TXE4 telephone exchange. *(5 min)*

A17 The main control units (MCUs) of a TXE4 telephone exchange are special-purpose processors that use program-control techniques to correlate information from the cyclic-stores and registers. According to the instructions in the stored program, the MCUs establish the required connections through the switching network of the exchange. The program for each MCU is stored on a read-only threaded-core store; each step of the program is stored in the form of a single wire threaded through an array of small magnetic core transformers. The program has a capacity of up to 5000 words and each word is defined by a wire threading 8 rows of cores. Pulses on the primary wires produce outputs in the secondary windings of the cores threaded and these output signals are used to form instructions.
[*Tutorial Note:* In the later TXE4A version of the exchange, the program is stored on integrated-circuit memories.]

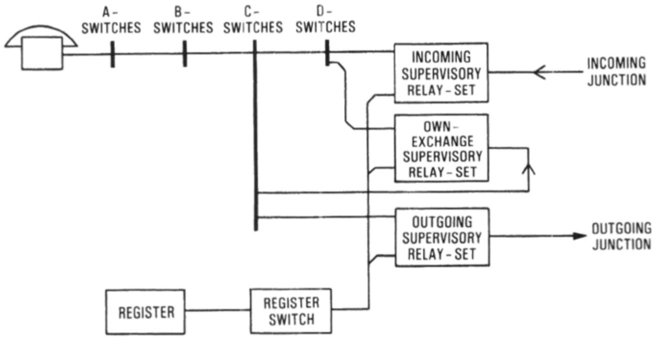
Q18 Draw a diagram showing the serial trunking sequence for an own-exchange call in a TXE4A telephone exchange. Identify both intermediate and final paths.

A18



Q19 Draw a simplified trunking diagram of a TXE2 telephone exchange showing A-, B-, C- and D-switching stages; incoming, own-exchange and outgoing relay-sets; registers and register switches. *(5 min)*

A19



Q20 Explain briefly the purpose of each switching stage in a TXE2 telephone exchange. *(5 min)*

A20 The purpose of the A-, B- and C-stages is to concentrate the traffic from the subscribers, which are low-traffic sources, in order to make efficient use of the supervisory relay-sets.

[*Tutorial Note:* Incoming circuits are high-traffic sources and can, therefore, be connected directly to the incoming supervisory relay-sets.]

Terminating calls from both own-exchange and incoming supervisory relay-sets pass through the D-, C-, B- and A-switches. The C-, B- and A-switches deconcentrate the traffic to the subscribers. The D-switch is added to improve access to the C-switches from the supervisory relay-sets and thereby reduce blocking. If the supervisory relay-sets were terminated on the C-switches, there would be only 5 possible paths from each relay-set to the subscriber.

SCOTTISH TECHNICAL EDUCATION COUNCIL

Certificate in Electrical and Electronic Engineering

Sets of model questions and answers for Scottish Technical Education Council (SCOTEC) subjects are given below. The questions illustrate the types of questions that students may encounter, and are useful as practice material for the skills learned during the course.

Where additional text is given for educational purposes, it is shown within square brackets to distinguish it from information expected of students under examination conditions. Representative time limits are shown for each question, and care has been taken to give model answers that reflect these limits.

We would like to emphasise that the model answers are not representative of questions set by any particular college.

SCOTEC: ELECTRICAL PRINCIPLES II

Students are advised to read the notes above

Q1 A voltage of the form $v = 340 \sin \omega t$ volts is applied to a pure inductor of reactance 100 Ω. Write down an expression for the current. *(4 min)*

A1 The peak voltage is 340 V. Therefore, the peak current is 340/100 = 3·4 A. In a pure inductor the current lags the voltage by $\pi/2$ radians.

Therefore, the expression for the current, i, is

$$\underline{i = 3{\cdot}4 \sin\left(\omega t - \frac{\pi}{2}\right) \text{ amperes.}}$$

Q2 (a) An 8 μF capacitor connected in series with a second capacitor gives a total capacitance of 3·6 μF. Determine the value of the second capacitor.

(b) What capacitance is obtained when the 2 capacitors in (a) are connected in parallel? *(5 min)*

A2 (*a*) Let the capacitance of the second capacitor be C_2 microfarads.

Then,
$$\frac{1}{3{\cdot}6} = \frac{1}{8} + \frac{1}{C_2}.$$

$$\therefore \quad \frac{1}{C_2} = \frac{1}{3{\cdot}6} - \frac{1}{8},$$

$$= \frac{8 - 3{\cdot}6}{28{\cdot}8},$$

$$= \frac{4{\cdot}4}{28{\cdot}8}.$$

$$\therefore \quad C_2 = \frac{28{\cdot}8}{4{\cdot}4},$$

$$= \underline{6{\cdot}5\ \mu\text{F}.}$$

(*b*) The resultant capacitance of the 2 capacitors connected in parallel is the sum of their individual capacitances and is equal to

$$8 + 6{\cdot}5 = \underline{14{\cdot}5\ \mu\text{F}.}$$

Q3 When a practical voltmeter or a practical ammeter is connected into a circuit, how does the reading indicated by the instrument relate to the true value of the circuit quantity. *(4 min)*

A3 The readings on the practical voltmeter and the practical ammeter are lower than the true values.

Q4 A magnetic circuit has a reluctance of 2·5 MH^{-1}; the coil in the circuit has 5000 turns and carries a current of 5 A. Determine the magnetic flux. *(4 min)*

A4 The magnetic flux, Φ, is given by

$$\Phi = \frac{IN}{S} \text{ webers,}$$

where I (amperes) is the current in the coil, N is the number of turns, and S (henrys^{-1}) is the reluctance.

$$\therefore \quad \Phi = \frac{5 \times 5000}{2{\cdot}5 \times 10^6} = \underline{10 \text{ mWb.}}$$

Q5 A parallel 7-plate capacitor has 2 mm of dielectric between plates. The relative permittivity of the dielectric is 5 and the cross-sectional area of each plate is 10 cm². Calculate the total capacitance. *(5 min)*

A5 The capacitance, C, of a parallel n-plate capacitor is given by

$$C = \frac{\epsilon_0 \epsilon_r A(n-1)}{d} \text{ farads,}$$

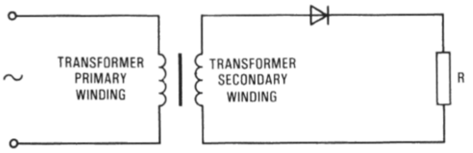
where ϵ_0 is the permittivity of free space, ϵ_r is the relative permittivity of the dielectric, A (metres) is the cross-sectional area, and d (metres) is the distance between the plates.

$$\therefore \quad C = \frac{8{\cdot}85 \times 10^{-12} \times 5 \times 10 \times 10^{-4} \times (7-1)}{2 \times 10^{-3}},$$

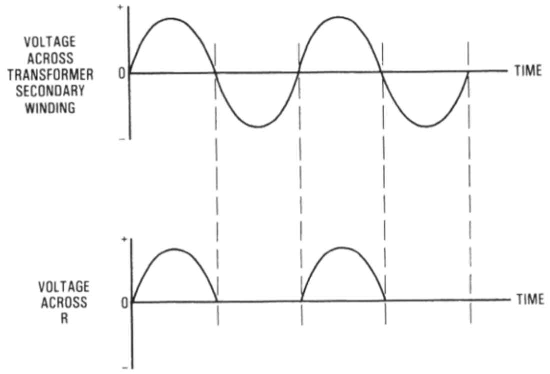
$$= \underline{132{\cdot}75 \text{ pF.}}$$

Q6 A resistor R is connected to the secondary winding of a transformer via a single diode. Sketch the circuit diagram and the voltage waveforms across the transformer secondary winding and resistor R. *(6 min)*

A6 The circuit diagram is shown in sketch (*a*) and the voltage waveforms are shown in sketch (*b*).



(*a*)



(*b*)

Q7 The energy stored in the magnetic field of a coil connected to a 10 V DC supply is 40 mJ. Determine the resistance of the coil if the inductance is 5 mH. *(6 min)*

A7 The energy in the magnetic field of the coil is given by

$$W = \tfrac{1}{2} L I^2 \text{ joules,}$$

where L (henrys) is the inductance, and I (amperes) is the current.

$$\therefore \quad I = \sqrt{\left(\frac{2W}{L}\right)} = \sqrt{\left(\frac{2 \times 40 \times 10^{-3}}{5 \times 10^{-3}}\right)} = 4 \text{ A.}$$

The resistance of the coil, R, is given by

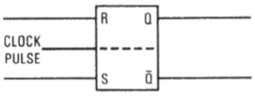
$$R = \frac{V}{I},$$

where V is the EMF of the supply.

$$\therefore \quad R = \frac{10}{4} = \underline{2{\cdot}5\ \Omega.}$$

Q8 Draw the British Standard symbol and the truth table for an RS bistable circuit. *(6 min)*

A8



Input		Output after $n+1$ clock pulses
R	S	Q_{n+1}
0	0	Q_n (no change)
0	1	0
1	0	1
1	1	indeterminate

Q9 (a) Define the following systems:

(i) analogue system,
(ii) digital system, and
(iii) programmable system.

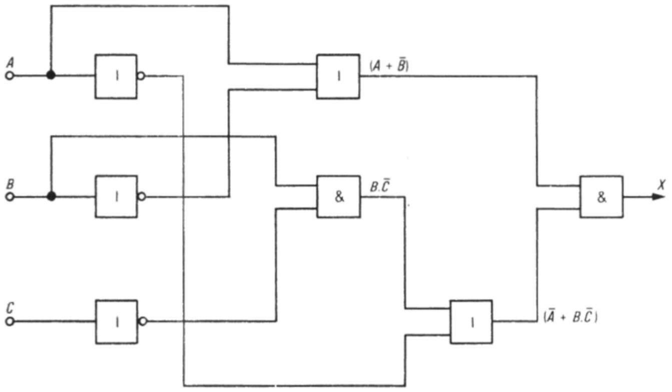
(b) Draw the truth table and a gating diagram using AND, OR and NOT gates for the expression $x = (\bar{A} + B.\bar{C}).(A + \bar{B})$. Assume that input C is the least significant input. *(20 min)*

A9 *(a) (i)* An analogue system is one in which all the variables are continuous and can have any value.

(ii) A digital system is one in which the variables can only take certain values. For example, in a binary system there are only 2 values.

(iii) A programmable system is one whose operation is governed by a set of instructions, or program.

(b)



A	B	C	$\bar{A}$	$\bar{B}$	$\bar{C}$	$(A+\bar{B})$	$(\bar{A}+B.\bar{C})$	$(\bar{A}+B.\bar{C}).(A+\bar{B})$
0	0	0	1	1	1	1	1	1
0	0	1	1	1	0	1	1	1
0	1	0	1	0	1	0	1	0
0	1	1	1	0	0	0	1	0
1	0	0	0	1	1	1	0	0
1	0	1	0	1	0	1	0	0
1	1	0	0	0	1	1	1	1
1	1	1	0	0	0	1	0	0

Q10 Two coils having 5000 turns (N_1) and 10 000 turns (N_2), respectively, are wound on a common iron core of mean length 80π cm and cross-sectional area 20 cm^2. The iron has a relative permeability of 500, and the coupling coefficient between the coils is 0·8.

Calculate:

(a) the self inductance of each coil;

(b) the mutual inductance; and

(c) the EMF in each coil, if a current of 2 A in the 5000-turn coil is reversed in a time of 5 ms. *(20 min)*

A10 *(a)* The reluctance, S, of the core is given by

$$S = \frac{l}{\mu_0 \mu_r A}\ \text{henrys}^{-1},$$

where μ_0 is the permeability of free space, μ_r is the relative permeability of the iron, l (metres) is the length of the core, and A (square metres) is the cross-sectional area.

$$\therefore \quad S = \frac{80\pi \times 10^{-2}}{4\pi \times 10^{-7} \times 500 \times 20 \times 10^{-4}},$$

$$= 2 \times 10^6\ \text{H}^{-1}.$$

The self inductance, L, of a coil with N turns and reluctance S is given by

$$L = \frac{N^2}{S}\ \text{henrys.}$$

Therefore, for the 5000-turn coil,

$$L_1 = \frac{N_1^2}{S} = \frac{5000 \times 5000}{2 \times 10^6} = \underline{12{\cdot}5\ \text{H},}$$

and for the 10 000-turn coil,

$$L_2 = \frac{N_2^2}{S} = \frac{10^4 \times 10^4}{2 \times 10^6} = \underline{50\ \text{H.}}$$

(b) The mutual inductance, M, is given by

$$M = k\sqrt{(L_1 L_2)}\ \text{henrys.}$$

where k is the coupling coefficient.

$$\therefore \quad M = 0{\cdot}8\sqrt{(12{\cdot}5 \times 50)}, = \underline{20\ \text{H.}}$$

(c) The EMF, E_1, induced in the 5000-turn coil when the rate of change of current in the coil is $\mathrm{d}I/\mathrm{d}t$, is given by

$$E_1 = L_1 \frac{\mathrm{d}I}{\mathrm{d}t} = \frac{12{\cdot}5 \times 4}{5 \times 10^{-3}} = \underline{10\ \text{kV.}}$$

Since the 10 000-turn coil is linked by the flux produced by the 5000-turn coil, the EMF, E_2, induced in the 10 000-turn coil is given by

$$E_2 = M \frac{\mathrm{d}I}{\mathrm{d}t} = \frac{20 \times 4}{5 \times 10^{-3}} = \underline{16\ \text{kV.}}$$

[*Tutorial Note:* A reversal of current results in a total change in current of twice the steady value; that is, if a steady current of 2 A is reversed, the current change is 4 A.]

Q11 A circuit consisting of a coil in series with a capacitive reactance of 20 Ω is connected across a 250 V, 50 Hz, supply. A current of 5 A at a lagging power factor is drawn from the supply and the power dissipated in the circuit is 750 W.

Determine the following:

(a) the resistance of the coil,

(b) the impedance of the circuit, and

(c) the inductive reactance.

Also, sketch circuit and phasor (voltage) diagrams. *(20 min)*

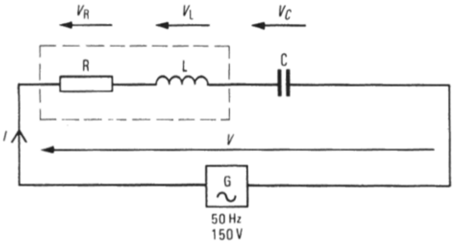
A11 *(a)* The circuit is shown in sketch *(a)*.
Power is dissipated only in the resistor and is given by

$$P = I^2 R\ \text{watts.}$$

$$\therefore \quad R = \frac{P}{I^2} = \frac{750}{5^2} = \underline{30\ \Omega.}$$

(b) The total impedance of the circuit, Z, is given by

$$Z = \frac{V}{I} = \frac{250}{5} = \underline{50\ \Omega.}$$



(a)

(c) The total impedance is also given by

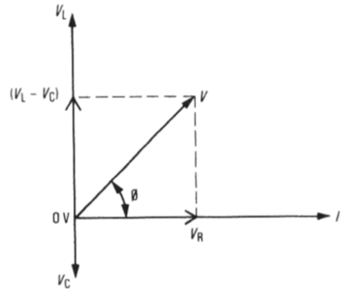
$$Z = \sqrt{\{R^2 + (X_L - X_C)^2\}},$$

where X_L is the inductive reactance of the inductor, and X_C is the capacitive reactance of the capacitor.

[*Tutorial Note:* X_L is greater than X_C since the power factor is lagging.]

$$\therefore \quad X_L - X_C = \sqrt{(Z^2 - R^2)},$$
$$= \sqrt{(50^2 - 30^2)},$$
$$= 40\ \Omega.$$
$$\therefore \quad X_L = 40 + X_C,$$
$$= \underline{60\ \Omega.}$$

The phasor diagram is shown in sketch *(b)*.



(b)

Q12 *(a) (i) Convert the denary number 47 into binary form.*
(ii) Convert the binary number 11 001 into denary form.

(b) Express the denary number 529 in binary form using the binary-coded-decimal (BCD) code with weighting 8421.

(c) Explain the function of the following parts of a program-controlled system:

(i) arithmetic and logic unit (ALU),
(ii) the address bus, and
(iii) the input/output port.

(d) Describe the main advantage that a program-controlled system has over a hard-wired logic system.

(20 min)

A12 *(a) (i)* [*Tutorial note:* A denary number can be converted into binary form by repeatedly dividing by 2 and writing down the remainder in reverse order.]

Quotient	Remainder
2)47	
23	1
11	1
5	1
2	1
1	0
0	1

$$\therefore \quad 47_{10} = \underline{101\ 111_2.}$$

(ii)
$$11\ 001_2 = (1 \times 2^4) + (1 \times 2^3) + (0 \times 2^2) + (0 \times 2^1) + (1 \times 2^0),$$
$$= 16 + 8 + 1,$$
$$= \underline{25_{10}.}$$

(b) [*Tutorial Note:* To convert a denary number into binary form using BCD with 8421 weighting, each denary digit is represented by 4 binary bits coded directly into binary form.]

Denary Number	5	2	9
8421 BCD	0101	0010	1001

(c) (i) The ALU performs arithmetic and logic functions on data under the control of the program. The control unit directs the sequence of operations and sends control signals to co-ordinate the flow of information between sections of the system.

(ii) The address bus is a set of wires which allows a memory or input/output device to be addressed. It usually has 16 wires, which allow it to address $2^{16} = 65\ 536$ memory locations (referred to as 64 K). The address bus is normally unidirectional.

(iii) The input/output port is a circuit which contains a number of electronic switches which either enable an input device (keyboard, tape recorder, etc.) to transmit information to the data bus or enable information on the data bus to be connected to an output device (for example, a video display unit).

(d) To alter a program in a hard-wired system (for example, one which comprises logic gates) the logic system must be redesigned. With a program-controlled system, the program can be altered easily by entering new instructions from a keyboard or punch tape.

Q13 *The magnetic path of a DC machine consists of a cast iron portion of length 80 cm and 2 airgaps, each of length 2 mm. The effective cross-sectional area of the magnetic path is 40 cm², and the coil of the machine has 3000 turns carrying a current of 2 A. The flux produced in the magnetic circuit is 5 mWb.*

Determine the relative permeability of the cast iron. *(20 min)*

A13 [*Note:* See below for key to symbols.]

For the magnetic circuit,

$$F_{\text{tot}} = IN = 3000 \times 2 = 6000\ \text{A}.$$

$$S_{\text{tot}} = \frac{F_{\text{tot}}}{\Phi} = \frac{6000}{5 \times 10^{-3}} = 1{\cdot}2 \times 10^6\ \text{H}^{-1}.$$

For the air gaps,

$$S_{\text{air}} = \frac{l_{\text{air}}}{\mu_0 \mu_{\text{r, air}} A} = \frac{2 \times 2 \times 10^{-3}}{4\pi \times 10^{-7} \times 1 \times 40 \times 10^{-4}},$$
$$= 0{\cdot}796 \times 10^6\ \text{H}^{-1}.$$

Therefore, for the cast iron core

$$S_{\text{iron}} = S_{\text{tot}} - S_{\text{air}} = 1{\cdot}2 \times 10^6 - 0{\cdot}796 \times 10^6,$$
$$= 0{\cdot}404 \times 10^6\ \text{H}^{-1}.$$

Also,
$$S_{\text{iron}} = \frac{l_{\text{iron}}}{\mu_0 \mu_{\text{r, iron}} A}.$$

$$\therefore \quad \mu_{\text{r, iron}} = \frac{l_{\text{iron}}}{\mu_0 A S_{\text{iron}}},$$
$$= \frac{80 \times 10^{-2}}{4\pi \times 10^{-7} \times 40 \times 10^{-4} \times 0{\cdot}404 \times 10^6},$$
$$= \underline{394.}$$

A: cross-sectional area of magnetic circuit (square metres)
F: magneto-magnetic force (amperes)
I: current in coil (amperes)
l: length of magnetic path (metres)
N: number of turns on coil
S: reluctance (henrys^{-1})
Φ: magnetic flux (webers)
μ_0: permeability of free space
μ_r: relative permeability
Subscripts
  tot: refers to the total magnetic path
  air: refers to the airgaps
  iron: refers to the cast iron core

Q14 *(a) A circuit of resistance 10 Ω takes a current of 1 A from a DC supply. When a practical ammeter is inserted into the circuit, the current falls to 0·8 A. Determine the resistance of the ammeter.*

(b) Two resistors of resistance 200 Ω and 1 kΩ, respectively, are connected in series across a 100 V DC supply. An ideal ammeter is used to measure the current in the circuit and a 4 kΩ voltmeter is used to measure the potential difference across the 2 resistors. Calculate the current in the circuit and the potential difference across the 200 Ω and 1 kΩ resistors for the following conditions:

(i) with the voltmeter disconnected,
(ii) with the voltmeter connected across the 200 Ω resistor, and
(iii) with the voltmeter connected across the 1 kΩ resistor.

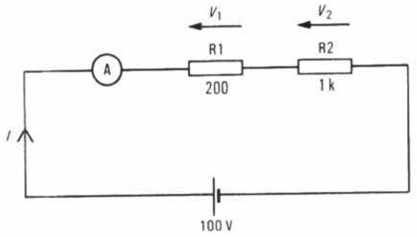
(20 min)

A14 (*a*) The supply voltage $= 1 \times 10 = 10$ V.

Therefore, the total resistance with the ammeter connected $= 10/0{\cdot}8 = 12{\cdot}5\ \Omega$.

Therefore, the resistance of the ammeter $= 12{\cdot}5 - 10 = \underline{2{\cdot}5\ \Omega}$.

(*b*) (*i*) The circuit conditions are shown in sketch (*a*).



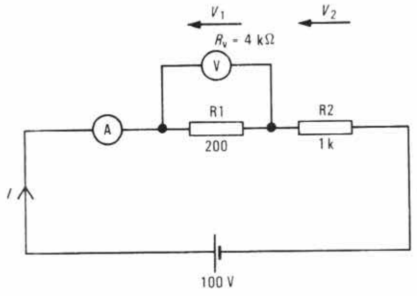
(*a*)

$$I = \frac{100}{1200} = \underline{0{\cdot}08333\ \text{A}}.$$

$$\therefore \quad V_1 = 0{\cdot}08333 \times 200 = \underline{16{\cdot}67\ \text{V}},$$

and,
$$V_2 = 0{\cdot}08333 \times 1000 = \underline{83{\cdot}33\ \text{V}}.$$

(*ii*) The circuit conditions are shown in sketch (*b*).



(*b*)

The total resistance, $R_{1//\mathrm{v}}$, of R1 in parallel with the voltmeter is given by,

$$R_{1//\mathrm{v}} = \frac{R_1 R_\mathrm{v}}{R_1 + R_\mathrm{v}} = \frac{200 \times 4000}{4200},$$
$$= 190{\cdot}5\ \Omega.$$

The total resistance in the circuit, R_t, is given by

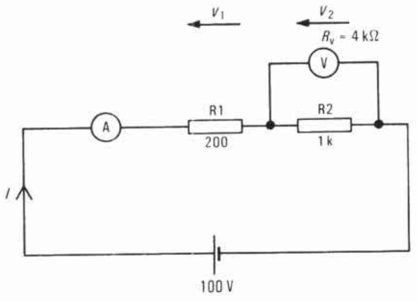
$$R_\mathrm{t} = R_{1//\mathrm{v}} + R_2 = 190{\cdot}5 + 1000,$$
$$= 1190{\cdot}5\ \Omega.$$

$$\therefore \quad I = \frac{V}{R_\mathrm{t}} = \frac{100}{1190{\cdot}5},$$
$$= \underline{0{\cdot}084\ \text{A}}$$

$$\therefore \quad V_1 = 0{\cdot}084 \times 190{\cdot}5 = \underline{16\ \text{V}},$$

and,
$$V_2 = 0{\cdot}084 \times 1000 = \underline{84\ \text{V}}.$$

(*iii*) The circuit conditions are shown in sketch (*c*).



(*c*)

The total resistance, $R_{2//\mathrm{v}}$, of R2 in in parallel with the voltmeter is given by,

$$R_{2//\mathrm{v}} = \frac{R_2 R_\mathrm{v}}{R_2 + R_\mathrm{v}} = \frac{1000 \times 4000}{5000},$$
$$= 800\ \Omega.$$

The total resistance in the circuit, R_t, is given by,

$$R_\mathrm{t} = R_{2//\mathrm{v}} + R_1 = 800 + 200,$$
$$= 1000\ \Omega.$$

$$\therefore \quad I = \frac{V}{R_\mathrm{t}} = \frac{100}{1000},$$
$$= \underline{0{\cdot}1\ \text{A}}.$$

$$\therefore \quad V_1 = 0{\cdot}1 \times 200 = \underline{20\ \text{V}},$$

and,
$$V_2 = 0{\cdot}1 \times 800 = \underline{80\ \text{V}}.$$

D. C. Ellacott

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